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Development of a Feather-Weight Inverter System

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Abstract

In this paper, we designed and developed a feather-weight inverter with timing capability to solve majorly the problem of bulkiness usually associated with conventional inverters. We realized the inverter by simulating its entire circuit on Proteus 2008 Software before developing it. During the developmental stage, we built a DC-DC boost converter circuit that steps up the voltage since the voltage supplied by the battery is insufficient to drive the load after converting to AC. A DC-DC boost converter is a power converter which converts DC input voltage to higher DC voltage. The DC-DC boost converter circuit boosts or step up the 12Vdc from the battery to 315Vdc which is then fed into H-bridge circuit to be converted to 220Vrms 50Hz AC signal. The designed and developed inverter met the desired specification as it was able to supply a voltage of 220Vrms. Timing capability was achieved with the integrated micro-controlled system which provide the user with the privilege of timing the inverter to supply power to a particular load within a time frame, thereby avoiding wastage of power and saving power for future use. The developed system performed satisfactorily.

Key words:DC-DC Boost Converter, H-Bridge Circuit, High Frequency Ferrite Core Transformer, PWM IC (SG3525), inverter, microcontroller

1.0 Introduction

The world all over is experiencing an increase in technological advancement. New equipment is being developed while old ones are replaced and some modified. Among the equipment undergoing such modifications include the inverter [1]. The inverter is a dc to ac converter which converts dc power to ac power at desired output voltage and frequency. The dc power input is obtained from a battery in this case, while it can also be obtained from magneto hydrodynamic generator, fuel cell, photovoltaic array, existing power supply network or from a rotating alternator through a rectifier [2]. In the absence of public utility supply, generators are used to produce power for the consumers in Nigeria and this has adverse effect on the environment in terms of air pollution which contributes to global warming. Also, noise pollution from generators is one of the environmental hazard affecting human as well as climate [3].

The design and construction of an inverter to convert dc to ac using an automobile battery is one of the numerous breakthroughs in modern technological development [4]. In this project, a light weight inverter with time-controlled capability was designed and developed. A feather weight inverter is an electrical equipment that uses high frequency transformer to convert dc to high frequency ac, back to dc and ultimately to standard-frequency 50Hz ac [5]. The desirable features of a light weight inverter are low cost, low weight or reduced size, silent operation and compactness [1, 5, 6]. In conventional inverter, the presence of iron-core transformer makes the system heavy, bulky and more expensive. A conventional inverter system is not very efficient because of the power loss during the voltage conversion process [6, 7]. So replacing the iron core transformer with a high frequency ferrite core transformer gives a more efficient design.

In the design of inverters, pulse width modulation (PWM) is used because of its circuit simplicity and rugged control schemes. It is characterized by a constant amplitude pulsed, whereby the width of the pulses are modulated to obtain inverter output voltage control and hence its harmonic content is reduced. In this work, high frequency converters are used because it makes the system compact and help to reduce cost [8]. However, H-bridge (Half bridge) is the simplest form of high frequency switching and uses fewer numbers of switches and it also has simple control. The term feather-weight comes from using high frequency switching which in turn allow for smaller inductors [9].

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2.0 Modifications and Methodology

In considering some light weight inverters, we discovered that one thing was common to them. They utilize the voltage from the Photovoltaic (PV) arrays or cells as the input voltage to the inverter directly and use switching devices to convert dc to ac, while neglecting the use of iron core transformers. However, in our methodology, we use non-photovoltaic light weight inverter that uses a battery simply to supply the input voltage (dc) to the inverter. We improved on the work presented in [10] while keeping its timing capability feature, thereby having an inverter with a more desirable features and high efficiency. Lastly, we integrated a micro controlled system, a power conservation system, which gives users the avenue of setting the time they want the system to supply power to a particular load, thereby avoiding wastage of power and unavailability of power for future use. In an attempt to lower cost and harmonies in the inverter, a DC-DC boost converter circuit was used to provide the inverter with a high voltage source for the generation of a pure sine-wave with Pulse Width Modulation (PWM) [4-6, 11]. In this time based feather-weight inverter, there are four load output ports, three of which are capable of being timed to operate within the required time specified by the user, while the other port can work as long as there is supply from the battery**.** Before the construction of the inverter, simulation work was carried out on Proteus 2008 Software to ascertain the feasibility of the proposed project. The work in this paper is also similar to that in [9]. The difference being that the work in [9] was simulated using Multisim software and circuit analysis was done, while in this paper Proteus software was used and the system was developed. In [9], a 5kVA inverter was designed for and 2.09kVA was achieved actually, while in this work a 1.5kVA inverter was designed for and we achieved 1.41kVA. Thus, the inverter designed in this work is more efficient.

3.0 Principle of Operation

The inverter has three major units namely - DC-DC boost converter unit, the H-bridge and the Mosfet driver unit and the control unit. The boost converter (Figure 1) boosts 12Vdc from the battery to 325Vdc through a four N-channel type Mosfets, PWM IC (SG3525) and a high frequency ferrite core transformer. This DC is fed into the H-bridge circuit (Figure 2) through its high sides and switches at a frequency of 50Hz supplied by the PIC microcontroller. The 50Hz switching signal goes to the inputs of the first MOSFET drivers (HI, LI). The outputs of the Mosfet driver (HO, LO) is then connected to one of the High side and low side of the H-bridge circuit. Same is done for the other two Mosfets using another Mosfet driver. However, the purpose of the switching driver is to make the Mosfet change states as quickly as possible so as to reduce accumulation of charges in the gate of the Mosfets that can destroy the Mosfets. The switching algorithm to produce a pure sine wave is done by the PIC microcontroller. The voltage control flowchart with PWM is shown in Figure 3, while the voltage control is done by an Opto-coupler circuit (see Figure 4) and the SG3525 IC which regulates the output and keeps it constant. Feedback voltage source is taken from the output of the secondary of the high frequency transformer of the boost converter. Increase in the output voltage, causes increase in the output from the Opto-coupler. This change is detected by one of the pins of the pulse width modulator IC (SG3525). Consequently, the pulse width generated is gradually reduced in proportion to the change. This is so that the high output voltage will begin to drop to nominal value and vice-versa.

The timing of each load port is done through an interface provided by a left and right push buttons. The right button is long–pressed to turn on the inverter when the non-time-able port is to be used. The left button is used to select the particular port of which a working time is to be set and the right button to set the desired working time. The internal operation of the timing is done by the microcontroller which provides control of the switch relays. When the set time is reached, the microcontroller automatically switches the relay associated with the particular load port selected and the load port deactivates. Figure 5 shows the timing algorithm flowchart. The System is protected from the negative effect of overloading by using a comparator (Figure 6) that compares the voltage level on each of its input pins to detect overloading. It compares voltage drop across a resistor known as current sensing resistor that has a very low resistance value to a set reference voltage (5V). The resistor is tied to ground (in series with the source terminals of the lower side of the H-bridge) of the boost converter. The whole current drawn by the load(s) connected to the inverter system flows through the low value resistor to the ground. An increase or decrease in the current flowing through the resistor results in a proportional increase or decrease in the voltage drop across the current sensing resistor. So when a current value greater than the maximum value of current the inverter can safely supply without cutoff; it results in a voltage drop across the current sensing element. This voltage drop is read by the comparator through the non-inverting pin connected in parallel with the current sensing resistor. Hence, the voltage is compared with the reference voltage on the inverting pin. At this time the voltage across the sensing resistor will be greater than that of the reference voltage. This causes the comparator to output a positive output voltage since voltage on the non-inverting pin is now greater than that on the inverting pin. This makes the diode connected to the output of the comparator to be forward biased and conduct. Thus, signaling the microcontroller to take appropriate action. The microcontroller upon receiving signal sends control signal to the SG3525 IC to stop working. The battery is charged by the battery charging unit (Figure 7) when mains supply (PHCN) is present. The battery charger unit has a 220/12V transformer that steps down the 220Vrms voltage from PHCN to 12Vrms. This step down voltage is then rectified and filtered to give a 12Vdc constant voltage which is supplied to the battery for charging it.

The microcontroller makes the whole system an embedded system. It is where the program that runs the whole system is embedded. The program was written in assembly language and burn into an 8051 microcontroller. The specific microcontroller that we used for this operation is the one known as AT89C52. The program was in assembly language and written on an Integrated Development Environment called MPLAB. The MPLAB compiler helped to convert the assembly language into Hexadecimal files also known as hex files, the hex files where now burned into the ROM of the microcontroller by the use of a Top Wind Universal Programmer. The microcontroller external component comprises of crystal oscillator, capacitors and resistors. The last part is the Display unit called the LCD. The LCD and the microcontroller are interfaced as shown in Figure 8. The complete circuit diagram is as shown in Figure 9 and worked satisfactorily when developed.

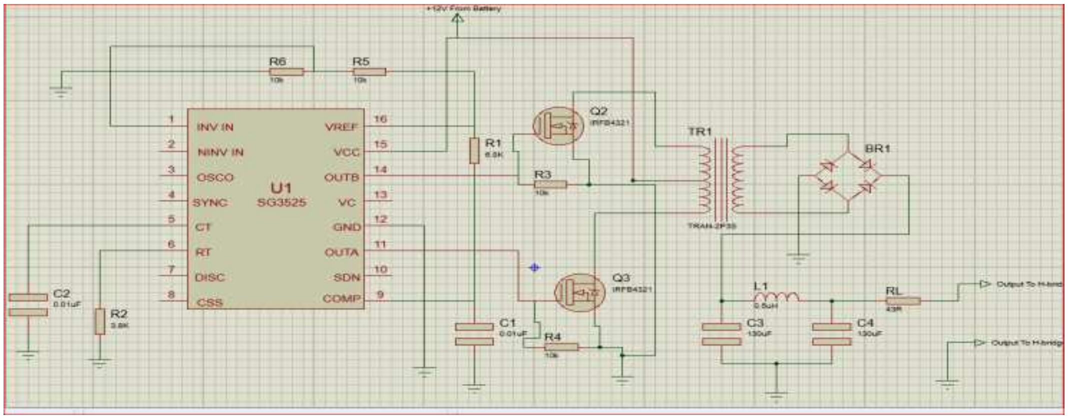

Figure 1: The DC-DC boost converter

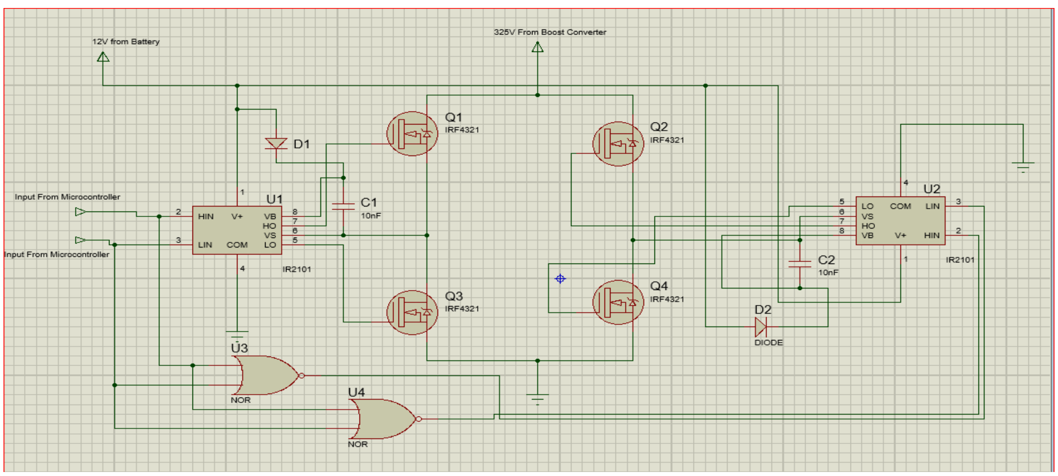

Figure 2: H-bridge with mosfet drivers

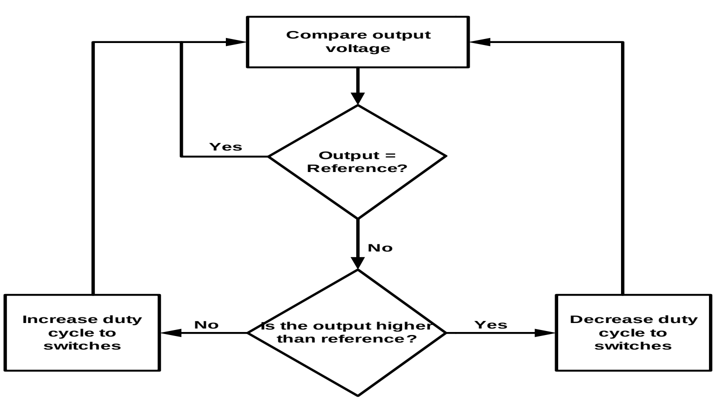

Figure 3: Voltage control flowchart with PWM.

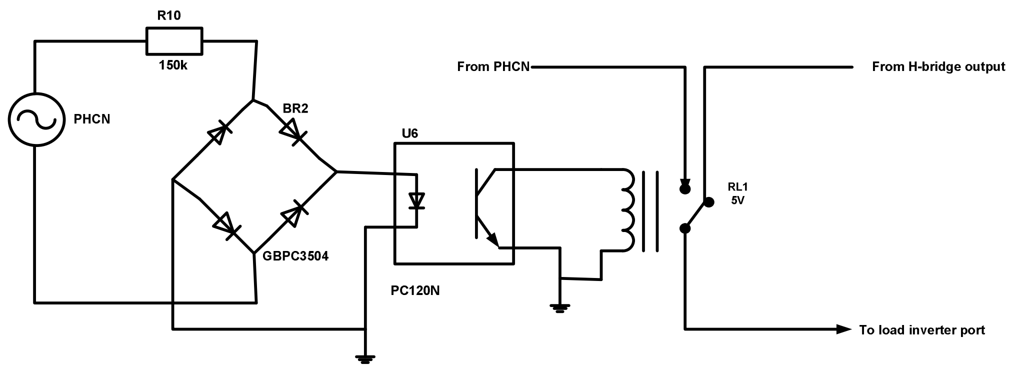

Figure 4: Changeover opto-coupler control circuit

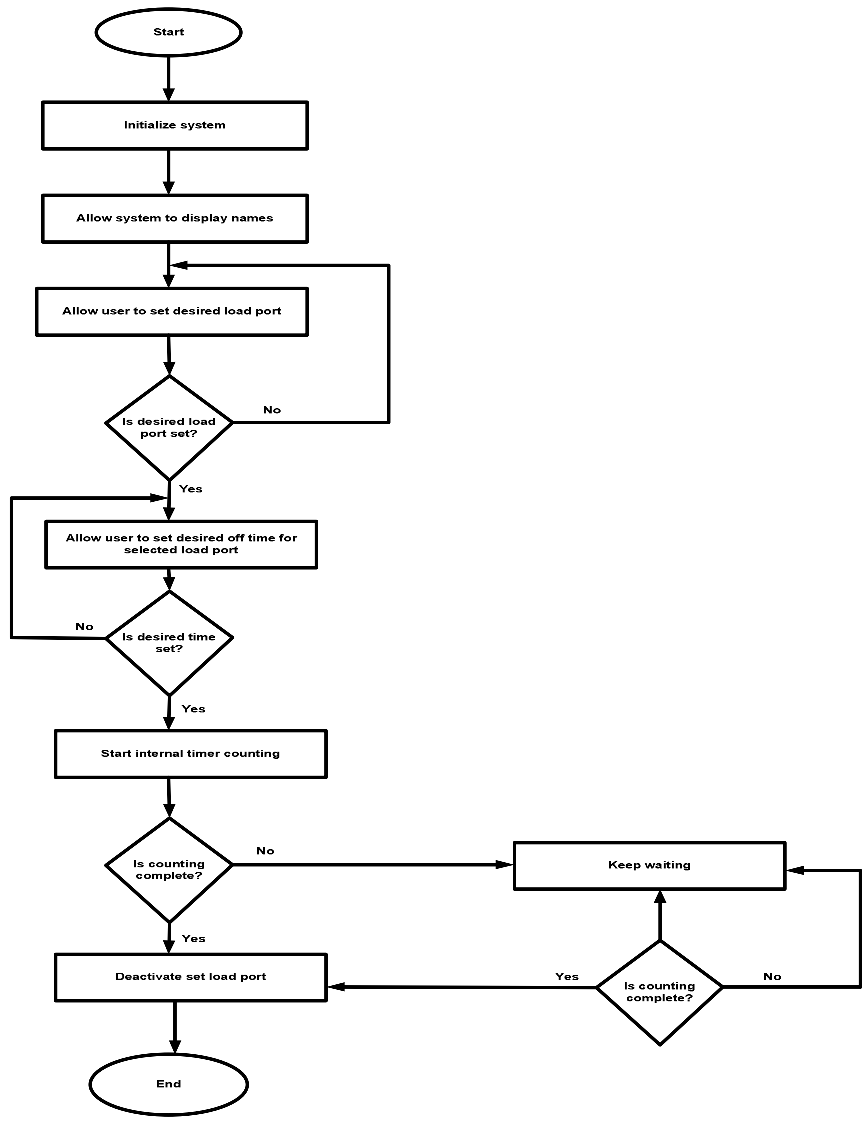

Figure 5: Timing algorithm flowchart